

Innovative Vitrification for Soil Remediation

**James G. Hnat, Ph. D
John S. Patten, Ph. D.
Norman W. Jetta, P.E**

**Vortec Corporation
3770 Ridge Pike
Collegeville, PA 19426
Telephone (610-489-2255)
Telefax (610-489-3185)**

1.0 INTRODUCTION¹

The Department of Energy's goal to clean-up its nuclear complex by the year 2019 requires the development of innovative technologies to convert soils contaminated by hazardous and/or radioactive wastes to forms which can be safely and readily entombed in accordance with current waste disposal methods. These technologies must be able to accomplish this task with minimum public and occupational health risks, with minimum environmental risks, and in a timely and economical manner. Additionally, the technologies must transform the hazardous and/or radioactive waste into a final form which has long-term stability to prevent migration of contaminants, and can thus be disposed in an environmentally safe manner. It is imperative that the technology not present any major obstacles to its own safe decontamination and decommissioning. Finally, the final waste form produced must be very stable since some of the radioactive materials have very long half-lives that greatly exceed the capability of institutional controls to protect the environment.

To accomplish its waste remediation and management missions, the Department of Energy has been evaluating and supporting the development of various technologies. Vitrification and other thermal treatment technologies are being extensively evaluated because of their ability to process a wide variety of organic, heavy metal and radionuclide contaminated wastes. Fossil fuel fired vitrification processes have the advantage of being very robust with regard to the wastes that can be effectively processed and the spectrum of final glass compositions that can be produced.

This paper summarizes the progress being made in the field implementation of a commercial scale Cyclone Melting System (CMS™) developed and patented by Vortec Corporation. Successful field implementation of the CMS™ technology will significantly increase the rate at which low-level, RCRA mixed, and TSCA bearing waste can be processed. This increased rate will translate into reduced clean-up costs to DOE. A major DOE demonstration program is currently in progress to validate the performance and operation of the Vortec Cyclone Melting System (CMS™) for the processing of LLW contaminated soils found at DOE sites. The Paducah Gaseous Diffusion Plant (PGDP) was selected for this demonstration because of its expressed interest in the technology, the impact the demonstration will have on the remediation effort at the site, and the site's willingness to participate in the financial support of the project.

¹ Project sponsored by U.S. Department of Energy's Morgantown Energy Technology Center, under Contract DE-AC21-92MC29120 with Vortec Corporation.

This DOE vitrification demonstration project has successfully progressed through the detail design and procurement portions of Phase 3 of the project. Phase 1 consisted of pilot scale testing with surrogate wastes and the conceptual design of a process plant for a generic DOE waste stream. The objective of Phase 2 was to develop a definitive process plant design for the treatment of wastes at a specific DOE facility, namely, PGDP. During Phase 2, a site specific conceptual design was developed for the processing of LLW soils and muds containing TSCA organics and RCRA metal contaminants. Phase 3 includes the construction and operation of a full scale demonstration at the DOE Gaseous Diffusion Plant.

During Phase 2, the basic vitrification process design was modified to meet the specific needs of the waste streams available at Paducah. The system design developed for Paducah has significantly enhanced the processing capabilities of the Vortec vitrification process. The overall system design, after several design iterations and component tests at vendor sites, now includes the capability to shred entire drums and drum packs containing mud, concrete, plastics and PCB's and will be adapted for processing bulk waste materials. This enhanced processing capability will substantially expand the total DOE waste remediation applications of the technology.

Vitrification trials were conducted during Phase 2 at Vortec's pilot scale vitrification plant located at the University of Pittsburgh Advanced Research Center in Harmarville, PA. The sampling of the effluent and influent streams taken during the tests confirmed that virtually all of the refractory radionuclides were retained in the glass and would not leach to the environment—as confirmed by both Product Consistency Tests (PCT) and Toxicity Characteristic Leaching Procedure (TCLP) testing. The organic contaminant was destroyed during testing with a Destruction and Removal Efficiency (DRE) of at least 99.99%, and semi-volatile RCRA metal surrogates were captured by the Air Pollution Control (APC) system. The data generated during these pilot tests relating to the partitioning of the contaminants throughout the system helped established system design criteria.

Construction at the Paducah, KY site for the 36 ton/day demonstration system was initiated on September 23, 1996. The State of Kentucky has judged that the CMS™ Vitrification Technology is a glass melting operation, and has issued an Air Permit for the process. Public comment for the RD&D permit was closed on October 2, 1996, and the RD&D permit is expected to be approved by the end of October, 1996. Construction and startup of the demonstration plant is scheduled to be completed in 1997. Following an initial 30 day qualification trial, extended duration testing is planned on additional waste streams available at the Paducah site. During this period, it will be possible to process approximately 80% of the contaminated soils stored Paducah.

2.0 TECHNOLOGY COMPARISONS

The data presented in Table 1.0-1 is a qualitative comparison of alternate remediation technologies, for DOE applications. The comparisons presented are for land fill, incineration, stabilization and vitrification alternatives. From the comparisons presented in the Table 1.0-1, vitrification technology is judged to be superior with regard to its ability to produce a vitrified product (final waste form) which has the highest level of chemical stability and its ability to contain inorganic contaminants. In addition, vitrification processes also effectively destroy organic compounds because of the high operating temperatures and residence times at these temperatures.

Table 1.0-2 presents a comparison of different classes of vitrification technologies. The data indicate that major advantages of the CMS™ technology are its low operating/maintenance cost, its high throughput capacity and its operational robustness while being able to produce a product which meets or exceeds all of the applicable product quality control and leaching criteria. The CMS™ has been demonstrated not to be as sensitive to variations in the waste stream's chemical composition as other vitrification processes.

Table 1.0-1. Comparison with Alternate Technologies

Alternatives	Advantages	Disadvantages
Landfilling	<ul style="list-style-type: none"> • Low initial capital investment 	<ul style="list-style-type: none"> • No waste volume reduction • Does not destroy organic compounds • Does not stabilize metals & radionuclides • Requires long term monitoring • Has significant potential for ground water contamination • Does not diminish generator long term liability • Low potential for resource recovery
Incineration	<ul style="list-style-type: none"> • Reduces waste volume • Destroys organic compounds 	<ul style="list-style-type: none"> • Preferred application is high organic content wastes • Generates substantial residuals • Residuals have leaching problems • Requires air pollution control • Hostile regulatory environment
Vitrification	<ul style="list-style-type: none"> • Reduces waste volume • Destroys organic compounds • Stabilizes inorganic contaminants • Products consistently pass TCLP and PCT • Long term product stability • Minimal long term generator liability • Reduced life cycle cost 	<ul style="list-style-type: none"> • Will require landfill of vitrified product only if radioactive (otherwise a value added product can be generated) • Requires some waste separation or pretreatment • Requires air pollution control
Stabilization	<ul style="list-style-type: none"> • Reduces landfill liability • Low initial capital cost 	<ul style="list-style-type: none"> • Significantly increases waste volume • No guarantee of effectiveness • Requires landfill monitoring • No reduced long-term generator liability • No significant life cycle cost advantage

Table 1.0-2. Comparison with Other Vitrification Technologies

Alternatives	Advantages	Disadvantages
Joule Heating	<ul style="list-style-type: none"> • Destroys organics • Stabilizes inorganics 	<ul style="list-style-type: none"> • Expensive (cost of electrical power and maintenance) • Low throughput capacity • Potential volume increase • Effectiveness limited by metals contamination, moisture, and carbon/organic content • Phase separation is common • Accelerated refractory wear • Requires air pollution control • Requires waste preparation • Organics may require post combustion
CMS™ Technology	<ul style="list-style-type: none"> • Very high throughput capacity • Destroys organics • Stabilizes inorganic contaminants • Organics contribute to energy source • Effective treatment of solids, liquids and gases • Multi-fuel capability • Low operating and maintenance cost • Produces a homogeneous product without phase separation • Low operating and maintenance cost 	<ul style="list-style-type: none"> • Requires waste preparation • Requires air pollution control
Molten Metal Processes	<ul style="list-style-type: none"> • Stabilizes waste • Provides volume reduction • Can process organics and metals 	<ul style="list-style-type: none"> • Very expensive • Very little operational data available • High maintenance and refractory wear • Phase separation inhomogeneous products • Requires air pollution control • Requires waste preparation • Requires post oxidation or after burning • High metals carryover
Plasma and Electric Arc Processes	<ul style="list-style-type: none"> • Provides volume reduction • Can treat solids, liquids or gases 	<ul style="list-style-type: none"> • High operating and maintenance costs • Low throughput capacity • Produces inhomogeneous products • Product leaching problems • Incomplete destruction of organics • Requires air pollution control • Requires post oxidation or after burning • Inefficient energy utilization • Limited applicability • High volatilization of metals, inorganics

3.0 PROGRAM OBJECTIVES

The principal objective of the METC/Vortec program is to demonstrate the ability of the Vortec CMS™ to remediate contaminated mixed waste, PCB contaminated waste, and other waste forms of interest to DOE by operating the CMS™ in the environment expected at PGDP, and producing glass which passes TCLP and PCT. The system has a nominal design capacity of 36 tons per day (TPD) with the capability for expansion to 72 TPD by adding oxygen enrichment.

Additional objectives will be met during the program, such as:

1. Establish an operating arrangement for an extended program for continued operation of the Demonstration Plant by Vortec, thereby supporting DOE's goal of implementing new Environmental Technologies.
2. Establish the glass chemistry requirements to achieve effective vitrification of contaminated waste found at the Paducah site; that is, given a particular waste, determine how its oxide composition must be modified to produce a vitrified product that will immobilize contaminants over the long-term.
3. Establish waste size reduction, moisture content, and the glass fluxing requirements.
4. Establish the cost of construction and operation of the CMS™ system.
5. Determine the Destruction Removal Efficiency (DRE) of the CMS™ for organic contaminants likely to be found in waste from DOE sites requiring remediation.
6. Verify the character of the off-gas and the effectiveness of the flue gas clean-up system at meeting the Air Permit requirement.
7. Conduct start-up, shake-down, and feasibility demonstrations using the fully integrated plant . The demonstration system will process approximately 160 barrels/day containing 30% moisture and an average weight of 450 lbs/barrel.

4.0 BACKGROUND INFORMATION

The Department of Energy's goal to clean-up its nuclear complex by the year 2019 requires the development of innovative technologies to convert soils contaminated by hazardous and/or radioactive wastes to forms which can be readily disposed in accordance with current waste disposal methods. Vortec has been working with DOE in developing the CMS™ to remediate various waste streams of concern to DOE. The Demonstration Plant under construction at PGDP will demonstrate at full scale the cost and operational effectiveness of the CMS™ process.

The unique features of the CMS™ technology make it a particularly cost-effective process for the vitrification of soils, sediments, sludges, and other solid wastes containing organic, metallic, and/or radioactive contaminants. Many of the benefits of the CMS™ technology recognized by the glass and hazardous waste management industry would also apply to DOE's ER&WM needs. Benefits with respect to DOE's needs are:

1. The ability of the CMS™ to produce a product which provides for long-term immobilization of heavy metals, toxic inorganics, and radionuclides. In numerous pilot scale tests conducted by Vortec, the CMS™ has demonstrated the ability to effectively process RCRA wastes as well as

surrogate contaminated soils. Simulated radionuclides and RCRA metals are effectively retained in the glass product and do not leach when tested using both the PCT and TCLP.

2. The CMS™ has demonstrated the ability to effectively oxidize and destroy organic contaminants. Tests performed by Vortec in the U-PARC facility with various carbonaceous materials such as cyanides and other organic contaminants found in most industrial waste, and anthracene and 1, 2- dichlorobenzene as surrogates for organic and PCB contaminants, have validated the organic destruction performance of the CMS™.
3. The CMS™ has demonstrated substantial flexibility with respect to the processing of various types of solid wastes and can accommodate substantial variations of feedstock composition. Vortec has completed more than 150 test programs using a variety of materials as feedstocks including U.S. Environmental Protection Agency (EPA) contaminated soils, flyash, baghouse dust, metal plating sludges, aluminum industry waste, steel industry waste and virgin glass making components. Soils with water content of up to 50 weight percent have been processed into glass products.
4. The CMS™ demonstrated the ability to oxidize and vitrify waste materials introduced as slurries, providing the capability for mixing contaminated or waste oils with various types of hazardous solids, soil wash process sediments, and mill tailings. In addition to contaminated soils, Vortec has demonstrated the ability to vitrify Hanford low level tank waste surrogates with a water content of approximately 70% liquid and 30% solids. The CMS™ has also demonstrated the ability to effectively vitrify a spectrum of metal plating sludges at 60% water content.
5. The CMS™ high temperature process components have water-cooled, steel walls providing for a sealed process which can be operated at negative pressure to prevent leakage of contaminated gases to the atmosphere. These water-cooled components can continue to operate in the event that unusual wear or spalling of refractory occurs until such time as the unit can be safely shut down.
6. The 36 TPD CMS™ demonstration unit is being designed to be transportable and modular, thus enabling wastes at several sites to be processed.
7. In the processing of substantial quantities of contaminated soils, the life cycle cost of the Vortec CMS™ is lower than other existing vitrification processes. In commercial applications, a 72 TPD CMS™ process unit typically has total processing costs in the range of \$50 - \$100 per ton of material processed. Radionuclide and PCB contamination increases the per-ton cost somewhat, depending upon the specific activity of the soil and the nature of the PCB contamination. Vortec estimates that the processing costs of low level waste with mixtures of TSCA or RCRA wastes at Paducah will be in the range of \$50 to \$200 per barrel for the Paducah drummed wastes.

4.1 PROCESS DESCRIPTION

The primary components of the basic CMS™ are a counter-rotating vortex (CRV) combustor and a cyclone melter. An artist's rendering of the basic CMS™ concept is shown in Figure 4.1-1. A unique feature of the process is the rapid suspension heating and oxidation of feedstock materials in the CRV combustor prior to the physical and chemical melting processes which occur within the cyclone melter.

The use of the Vortec CRV combustor in conjunction with a cyclone melter distinguishes the Vortec combustion and melting technology from other types of cyclone combustion systems. In the CMS™ process, granular glass-forming ingredients and other feedstocks are introduced into the top region of the CRV combustor along with fuel and combustion air. As a result of the intense counter-rotating vortex mixing, it is possible to achieve stable combustion in the presence of large quantities of inert particulate matter (solids-to-gas mass ratios on the order of 1:1). Both convection and radiation heat transfer mechanisms contribute to the rapid heating of the feedstock materials within the CRV combustor. Any organic contaminants in the feedstocks are also effectively oxidized.

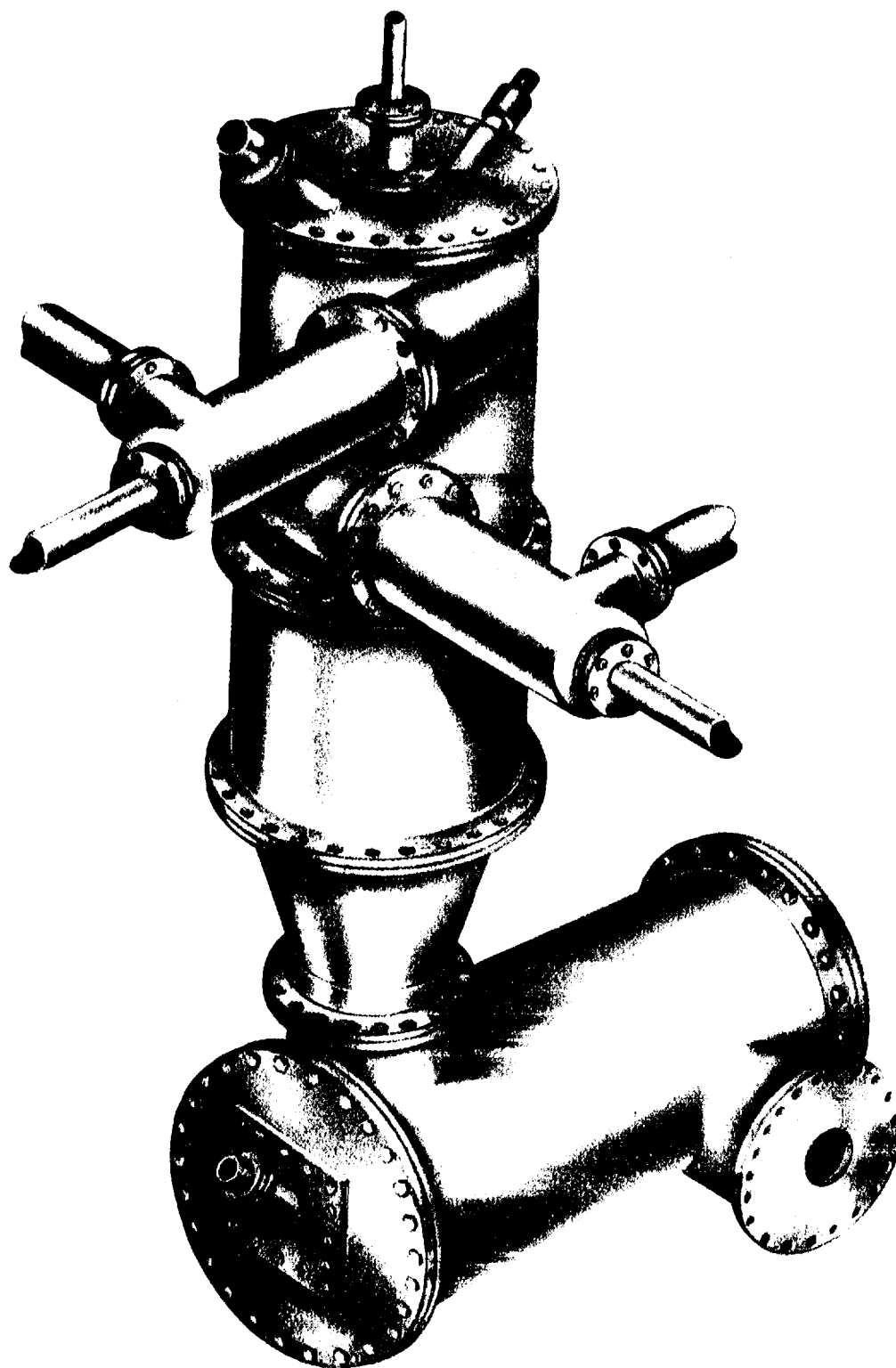


Figure 4.1-1. Artist Rendering of Basic Combustion/Melting System

The melted material formed in the cyclone melter and the combustion products exit the melter through a tangential channel and enter a separator-reservoir (not shown in the figure) where a pool of molten material exits the reservoir through a bottom or side tap. The flue gases exhaust to a heat recovery unit for combustion air preheating. The flue gas exiting the heat recovery unit is treated in an air pollution control assembly prior to being exhausted out the stack. As a result of the high thermal efficiency of the Vortec CMS™, the flue gas flow rates are relatively modest. Because the temperature and composition of the vitrified product can be closely controlled, the amount of process fuming (volatile carryover) can also be minimized.

The average gas-solids suspension temperature leaving the CRV combustor is typically on the order of 2000°F to 2700°F, and is a function of the product being vitrified. The process temperatures in the cyclone melter are typically in the range of 2000°F to 3000°F, depending on the melting characteristics of the feedstock being processed. The nitrogen oxide emissions have been found to be substantially lower than those which occur in conventional cyclone combustors. Excess air levels are typically in the range of 5 to 20% depending on the makeup and the nature of the feedstock being processed.

Heat rates demonstrated by the Vortec pilot scale facility typically ranged between 3.0 and 6 million Btu/ton at a glass production rate of 15 TPD. This heat rate is 50% to 80% lower than heat rates for conventional gas-fired glass melting at similar capacity. The energy savings are primarily due to more efficient heating of the glass ingredients in suspension by the products of combustion and lower structural heat losses due to the small physical size of the process components. The CMS™ can also accommodate the use of a variety of fuels, such as oil and coal-derived fuels, and even organic waste materials.

The CMS™ pilot system has demonstrated NO_x emissions of less than 4 pounds per ton of vitrified product, meeting the California emission standard for glass melters—currently the most stringent in the United States. The CMS™ demonstration plant is designated as a glass melter by the state of Kentucky the NO_x emissions rate is set, by the air permit, at 100 tons/yr. With natural gas as the primary fuel, the NO_x emissions, calculated as NO₂, have typically been approximately 2 pounds per ton of product. Rapid temperature quenching of the combustion products by the inert solid particles and staged combustion are the primary means of limiting NO_x emissions. Tests conducted for Hanford using a high nitrate concentration tank simulant resulted in no visible plume leaving the pilot plant's stack.

4.2 PREVIOUS RESEARCH ACCOMPLISHED

After four years of design evolution under various DOE and EPA programs, the CMS™ is completely operational at the U-PARC test facility. Vortec's system has demonstrated the production of glass and the vitrification of a variety of feedstocks, including:

- EPA surrogate soils,
- DOE surrogate soils,
- Spent Pot Liners (K-088) wastes
- Coal fired boiler ash,
- Sewage Sludge ash,
- Auto shredder residue ash
- Municipal solid waste incinerator ash,
- Metal Plating Sludges
- Fiberglass waste with organic contaminants,
- Dusts containing heavy metals and organic materials,
- Electronic industry wastes
- High sodium content tank waste surrogate

5.0 RESULTS

Vortec completed the verification testing and established the plant design requirements in Phase 2. Vortec is continuing the development, construction, and operation of the CMS™ Demonstration Plant during Phase 3. As of October 1, 1996, approximately 100% of the equipment has been specified and is in the bidding process. Construction at the site has been initiated, and a site dedication was held on October 16, 1996. The Air Permit has been issued by the State of Kentucky, and the RCRA RD&D permit public hearing has been held and the permit is expected momentarily. Vortec believes that the CMS™ technology is at the stage of development that will result in a mature process that is directly applicable to a large number of DOE Environmental Restoration and Waste Management (ER&WM) needs. Vortec is developing the CMS™ technology to commercial readiness, with the intention of economically meeting all public, occupational, and environmental health and safety requirements for remediation technology. Commercial offerings of the CMS™ technology, in plant sizes up to 200 TPD, have been made during the last year. A 50 TPD CMS™ system is in the start up process with a major industrial client.

5.1 Surrogate Test Results

A total of seven soil vitrification trials were conducted at Vortec's pilot scale vitrification plant located at U-PARC during Phase 2 of the program. The results of these tests were presented in Reference 1.

Glass samples obtained during the pilot tests using a surrogate Paducah waste streams indicated that the TCLP extract contained very little measurable quantities of metals and in all cases were significantly below EPA TCLP limits. PCT test results indicated a Na-normalized leach rate of 0.0032 to 0.015 grams of glass/square-meter/day. The PCT specification for nuclear glasses is a Na-normalized leach rate of no greater than 1.0 grams of glass/square-meter/day.

The best data available from DOE-Paducah indicated that the low level waste stream (soil) contained small amounts of organic materials and small amounts of heavy metals, uranium, and plutonium. It is expected that a PCB contaminated waste stream will be made available by Paducah and tested by Vortec. The surrogate used during the pilot test was 1, 2 dichlobenzene at a concentration approximately of 1000 PPM, a concentration well beyond what is expected in the actual low-level waste stream. The testing focused on establishing the DRE for this chemical compound. The CMS™ pilot system consistently demonstrated a 99.9% DRE while having a total system gas residence time of less than 1 second. With the addition of a recuperator to the CMS™, a commercial or demonstration system would have a gas residence time in excess of 3 seconds, as required for the destruction of PCB's.

Cerium was included at 500 PPM as a surrogate for uranium or plutonium, and the semi-volatile RCRA metals lead and cadmium were also included. Vortec has shown in many pilot tests that approximately 95% to 100% of the non-volatile RCRA metals report to the glass.

5.2 DESIGN PROGRAM-INTEGRATED DEMONSTRATION PLANT

5.2.1 System Requirements

The major system requirements for the Demonstration Plant are as follows:

1. Accept drummed waste streams with up to 30% moisture. The nominal processing capacity of drummed waste found at Paducah is 160 drums per day. (Note that if the moisture content is greater than 30%, it still can be processed but at reduced capacity). Provisions should be made to, at some later date, enrich the combustion air to approximately 40% oxygen, thereby allowing for growth in capacity to approximately 320 drums per day.
2. Targeted waste forms are 55 gallon drums of contaminated soils containing debris such as wood, plastic, and small amounts of concrete with of re-enforcing rod. The system will have the capability of processing entire drums, including plastic overpacks, plastic liners, and frozen drums. This will minimize health and safety risks and minimize waste characterization analysis costs.
3. The process will be capable of processing waste containing low-level amounts of radionuclides, TSCA, and RCRA contaminants.
4. The Demonstration Plant will be transportable and modular allowing use at multiple DOE sites and /or multiple locations at a single site. Process equipment will be skid-mounted to the maximum extent possible for installed on concrete pad foundations.
5. The Demonstration Plant will be capable of processing a wide variety of physical and chemical waste forms throughout the DOE complex. The wastes include soils, sediments, and/or sludges contaminated with hazardous wastes and low-level radioactive wastes. At Paducah both volatile (Technetium) and nonvolatile (Uranium, Neptunium, Thorium, and Plutonium) radionuclides are present at low levels in the in the waste stream. The eight heavy metals

regulated by 40 CFR 261.24 are also present in the soil. Organic materials that can result in Hazardous Air Pollutants regulated by State of Kentucky 401 KAR 63.022 are also present in selected waste streams. Optional waste streams may include but are not limited to: personnel protective equipment (PPE), HEPA filters, treated scrubber/ESP water particulate (a slip stream is required to control particulate build-up) and spent ion exchange materials.

6. The waste streams are fed, in dry form, to the melting system with a particle size no greater than minus 30 mesh and a moisture content that enables the material to flow freely. The soils at Paducah, as received, can have a moisture content of 30% and a size distribution well beyond the desired 30 mesh maximum; therefore, drying and grinding processes are included as part of the feed preparation subsystem.
7. The system will produce a glass frit, a chemically stable and reduced volume final waste form, that will pass the Toxicity Characteristic Leaching Procedure. The Air Pollution Control (APC) system will be required to meet DOE/EPA and the State of Kentucky standards for the removal of hazardous material and radionuclides. A venturi scrubber followed by a single Wet Electrostatic Precipitator (WESP) and HEPA filters are specified to meet the requirements of the site's environmental regulations. This APC system is considered by the State of Kentucky to be the best available technology.
8. The APC process water will have a slip stream to a wastewater treatment process to remove radionuclides and other solids.
9. The vitrified product generated as a result of testing will be disposed on-site or at an approved DOE radioactive waste repository and will be the responsibility of DOE-Paducah.
10. DOE-Paducah obtained the Air Permit, and the RCRA RD&D permit. DOE-Paducah will obtain a waste water permit modification needed to process the waste streams in the CMS™ demonstration.
11. DOE-Paducah and Vortec will jointly prepare the Operation and Maintenance manual and Health and Safety manual and prepare for the readiness review.

5.2.2 Demonstration Plant-System Description

An isometric drawing of the plant arrangement is shown in Figure 5.2-1. The system flow diagram is shown in Figure 5.2-2. The demonstration plant has been designed to the maximum extent possible as a transportable and modular system. The majority of the individual, skid mounted components have the capability to be transported by truck without special permits.

As is indicated in the system diagram Figure 5.2-2, contaminated soil is first transported by DOE in drums from the DOE-PGDP storage area to the vitrification facility. There is always at least a three day

supply of the material in the storage area. Soil samples collected prior to the 30 day demonstration test will be used to determine the batch composition.

Feed Preparation System

The process of vitrifying the soil begins in the Feed Preparation Subsystem. It consists of:

- (1) transportation of drums to the drum shredder for introduction to the feed preparation system,
- (2) a drying, crushing, metal and plastic separation process to assure that a "clean" material enters the grinding operation,
- (3) a grinding operation to generate the proper particle size.

To preclude the escape of dust particles when dumping or transporting the soil, all the conveying systems will be designed with an enclosure and operate under negative pressure. In addition, all hoppers and transfer points (dumping points) will also be enclosed and will be under negative pressure. The dust laden air from these devices will pass through a dust collector for particle removal. Solids collected in the dust collector will be transported back into the system. Discharge from the dust collector will pass through a parallel pass HEPA filter system.

The sized and dried waste is transported to a storage silo. Glass making additives are mixed with the soil. Additives (limestone and soda ash) are used to aid in glass forming, obtaining the proper glass properties, or modifying the temperature-viscosity curve. The blending system consists of storage silos and pneumatic feed system for the delivery of the soil and additives to a blend tank. Batch mixing precedes feeding into the Cyclone Melting System.

Cyclone Melting System (CMS™)

The CMS™ components consist of a counter-rotating vortex (CRV) preheater, a cyclone melter (CM), a separator/reservoir, and a recuperator heat recovery unit.

The prepared feedstock is introduced into the CRV preheater through injectors located at the top of the combustor. Combustion air, which has been heated by waste heat in the recuperator, is mixed with propane fuel in the inlet arms of the combustor. Auto ignition occurs as the fuel/air mixture enters the high temperature region of the combustor, and the resulting combustion products raise the temperature of the feedstock as it enters. Heated feedstock flows through the CRV to the Cyclone Melter, the feedstock reacts in the liquid layer deposited on the walls of the CM, producing the glass. The radionuclides and heavy metals are chemically bonded into the glass. The glass product and the exhaust gases exit the CM through a tangential exit channel and enter a glass/gas separation assembly (separator/reservoir).

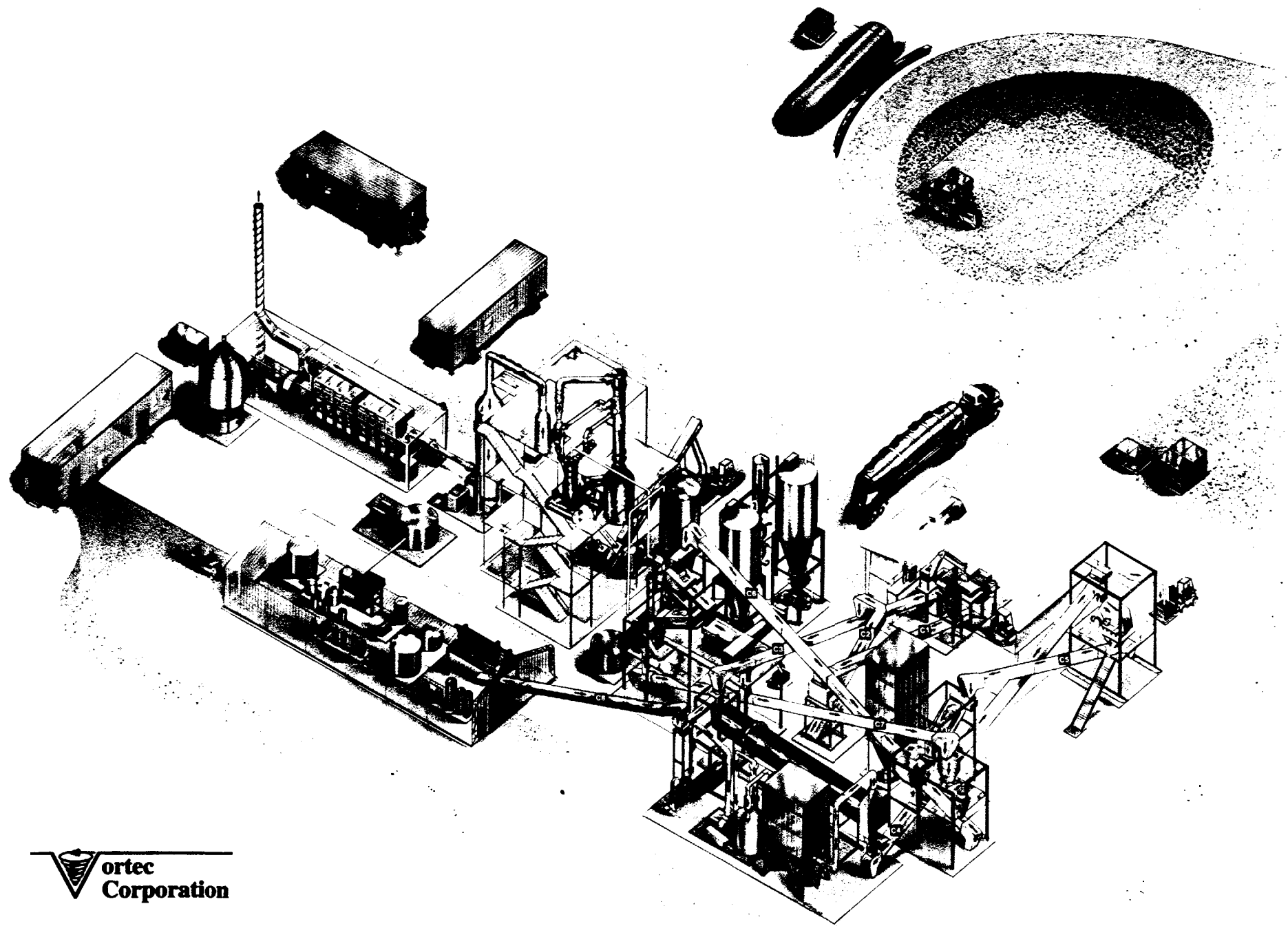


Figure 5.2-1. Isometric Drawing of Plant Arrangement

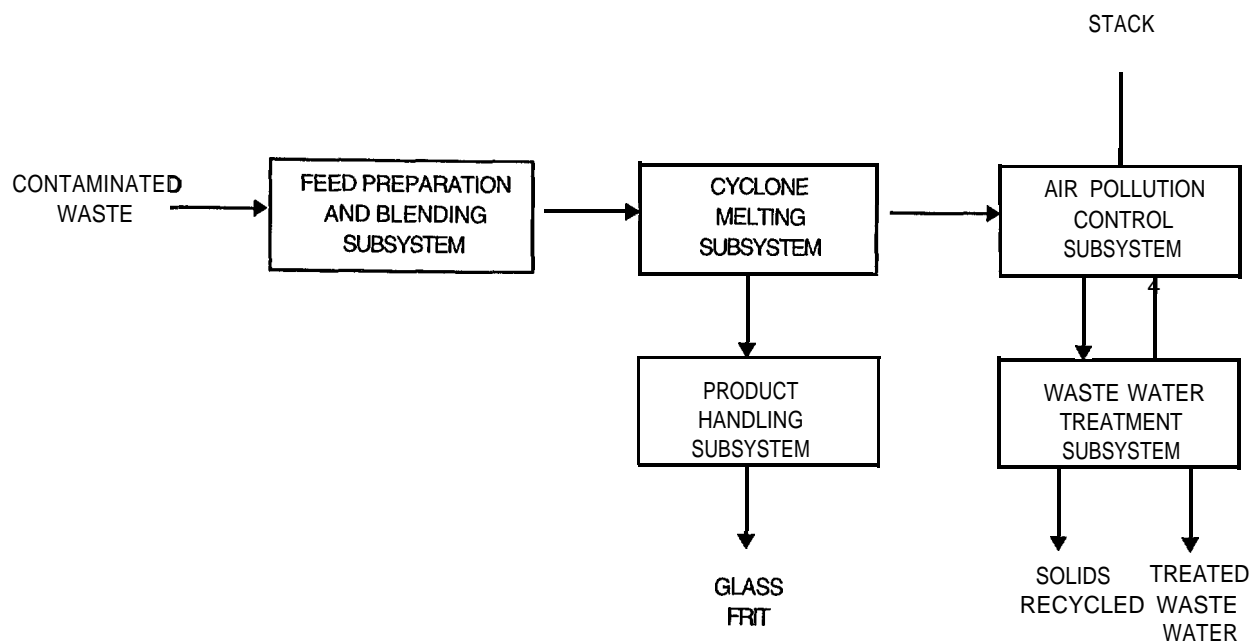


Figure 5.2-2. System Flow Diagram

The primary functions of the separator/reservoir are to separate the combustion products from the melted material and to provide an interface with a vitrified product handling system. The hot exhaust products exit through an exhaust port which is the interface for the recuperator. The recuperator utilizes the waste heat to preheat combustion air going to the CMS™. Molten glass flows out the separator/reservoir to the Vitrified Product Handling System.

Vitrified Product Handling System

The molten product from the CMS™ will be water quenched to produce a cullet approximately 1/8" in average size. The cullet will be transported by conveyor to ST-90 boxes. The ST-90 boxes, when full, will be moved to a pick-up area for pick-up and disposal by the DOE-Paducah.

Air Pollution Control System

The Air Pollution Control System will consist of a wet electrostatic precipitator (WESP) system for particulate collection preceded by a venturi scrubber. The scrubber will remove large particulate from the flue gas stream as well as serve the function of reducing the flue gas temperature to protect the APCS components. Other equipment in the APCS consists of an air heater, HEPA filters, induced draft fan, and an exhaust stack.

After removal of small particles in the WESP, the temperature of the off-gas is raised in an off-gas heater prior to entering the HEPA filter for removal of fine particles. Redundant HEPA filters are used to facilitate maintenance. The off-gas exits the HEPA filters and flows from the system through the exhaust stack.

Waste Water Treatment System

The Demonstration Plant also includes a waste water treatment system to remove radionuclides from the process water used in the venturi scrubber and WESP. This system consists of a clarifier, a filter press, sand filter, ion exchange unit, and various pumps and tanks.

Process water from the WESP flows through a wastewater tank, a chemical precipitation tank for chrome removal, and on to a clarifier. The solids from the clarifier, which contain some contaminants not captured in the glass, are dewatered in a filter press and are returned to the Feed Preparation System.

Radionuclides are removed by first filtering the supernate water in a sand bed. The solids are removed periodically from the sand bed by back flushing with the treated water, and the backwash is reintroduced into the clarifier. Radionuclides are removed through ion treatment. The treated effluent is stored in a holding tank for reuse as quench water within the quencher/venturi scrubber.

Instrumentation and Control System

The Instrumentation and Control System consists of the sensors, electronics, instrumentation, computers, and programmable logic controllers (PLC) to control the process in real time, gather data for analysis on system and equipment performance, and monitor process offgas. The control system will be automated to the maximum possible extent. Controllers shall be provided with the capability to be manually operated so that the combustion air blower and cooling water pumps can be operated in case of system failure. The system will be capable of being shut down in emergency situations in a controlled manner using the auxiliary power unit and structured logic. Proven industrial controls and electronics are used. Industrial PLC's enhance reliability. Multiple monitors are capable of being switched to allow individual subsystem processes to be monitored. In addition to collecting data for process and equipment evaluation, the system incorporates a Continuous Emissions Monitoring System for the off-gas.

5.2 OPERATIONS DESCRIPTION

To demonstrate the effectiveness of the technology, 400 hours of start-up and functional testing are planned, followed by a 30-day period of testing.

6.0 SUMMARY OF RESULTS

Vortec completed Phases 1 and 2 of a three phase program to design, construct, and demonstrate the effectiveness of the CMS™ technology at remediating soils contaminated with both heavy metals and radionuclides. At the conclusion of Phase 2, the ability of the CMS™ to vitrify soils similar to the soil found at the DOE-Paducah was demonstrated. The vitrified product passed the TCLP as well as the PCT for leachability of a glass being used to contain radionuclides.

Phase 3 of the project has been initiated. The final design of a 36 TPD Demonstration Plant to process low-level waste is essentially complete. The Air Permit has been issued by the State of Kentucky and the RD&D permit's period for public comment ended October 2, 1996. The issuing of the permit is expected by the end of October. Construction of the plant commenced late in September with a site dedication was held on October 16, 1996. The 30 days of demonstration testing are scheduled to be completed in early 1998.

ACKNOWLEDGMENT

The authors wish to acknowledge the contributions of DOE-METC COR Mr. Cliff Carpenter. The period of performance for Phase 3 of the contract is February 1995 through January 1998.

REFERENCES

Reference 1: J. G. Hnat, J. S. Patten, N. Jetta. Innovative Vitrification for Soil Remediation presented at Morgantown Energy Technology Center, Environmental Technology Through Industry Partnership, October 3 - 5, 1995.

***Environmental Technology Development Through
Industry Partnership***

***Vitrification Technology Program
for
Soil Remediation***

By

Vortec Corporation

Contract No. DE-AC21-92MC29120

*C. Carpenter COR
Morgantown Energy Technology Center
Morgantown, WV
October 22-24, 1996*

PRESENTATION OVERVIEW

- **PROGRAM DESCRIPTION**
 - Objectives
 - Phases & Schedule
- **TECHNICAL APPROACH**
 - System Requirements
 - Design and Features
- **BENEFITS**
- **PROGRAM PARTICIPANTS**
- **ACHIEVEMENTS**
- **CONCLUSIONS**
- **PLANS FOR TECHNOLOGY TRANSFER**
- **FUTURE PROGRAM WORK**

PROGRAM OBJECTIVE

Demonstrate the Ability of the Vortec 36 TPD Cyclone Melting System (CMS™) to Remediate DOE Contaminated Mixed Waste and Other Waste Forms by Producing Glass Which Passes TCLP and PCT.

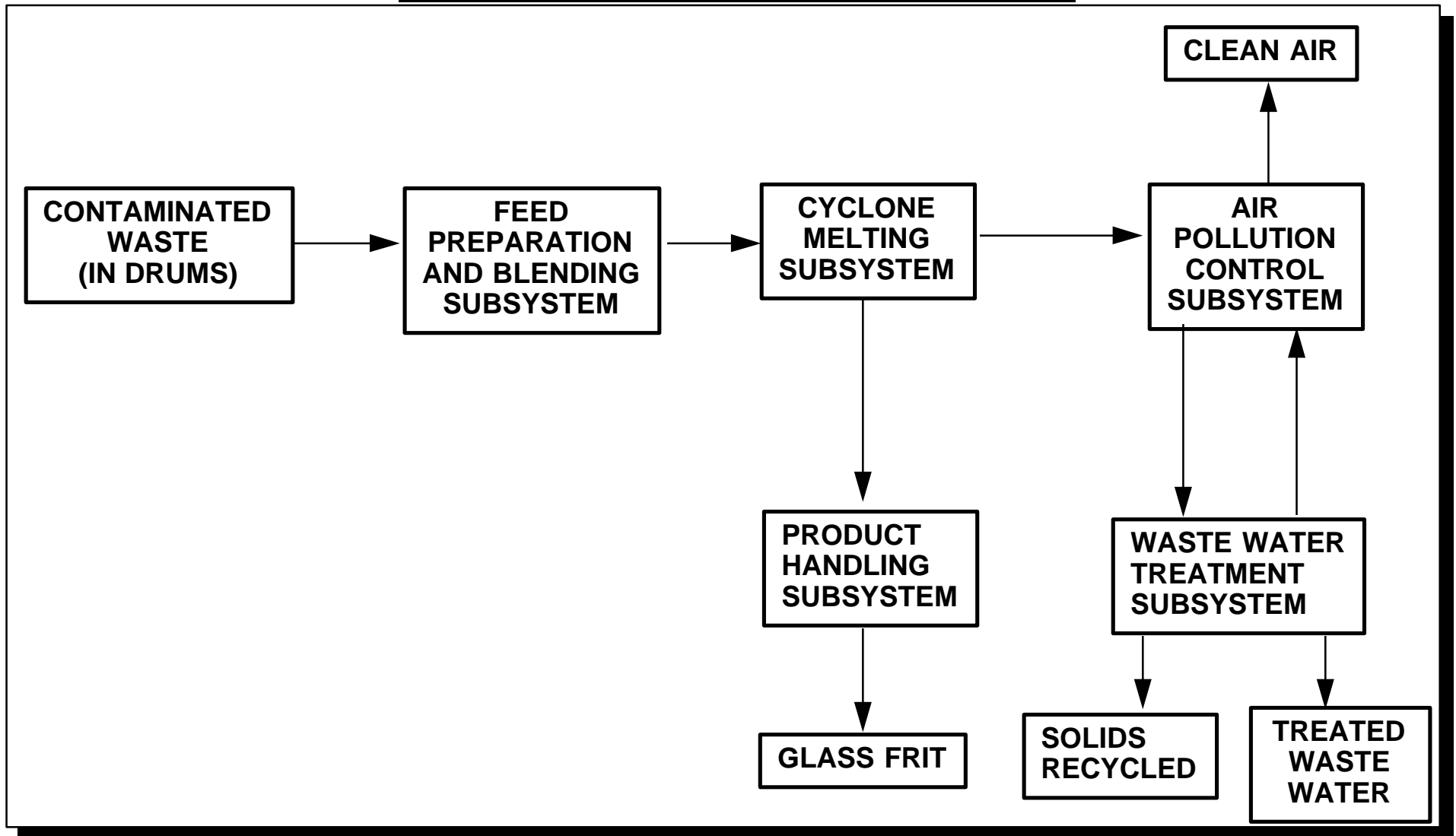
PROGRAM SCHEDULE

<u>MILESTONE</u>	<u>START/COMPLETE</u>
PHASE 1 CONCEPT DEFINITION	MAR. '93/DEC. '93
PHASE 2 SYSTEM DESIGN & WASTE QUALIFICATION	
– HANFORD SYSTEM	JAN '94/DEC. '94
– PADUCAH SYSTEM	FEB. '95/JUL. '95
PHASE 3 IMPLEMENTATION	
– FINAL ENG. & FABRICATION	OCT. '95/JAN '97
– CONSTRUCTION	OCT. '96/AUG. '97
– SYSTEM DEMONSTRATION	SEPT. '97/DEC '97
– FINAL REPORT	JAN. '98
PHASE 3 EXTENSION	JAN. '98 - JAN. 2000

SYSTEM REQUIREMENTS

- 1. NOMINAL 36 TPD WASTE PROCESSING CAPACITY**
- 2. TRANSPORTABLE & MODULAR SYSTEM**
- 3. TARGET WASTE STREAMS**
 - Low Level Radioactive Wastes (LLW)**
 - RCRA Mixed Waste Streams**
 - TSCA (PCB) Contaminated LLW**
- 4. SATISFACTION OF ALL DOE DEFINED HEALTH & SAFETY REQUIREMENTS**
- 5. DEMONSTRATION PLANT TO CONFIRM CMS™ PERFORMANCE FOR APPROXIMATELY 30 DAYS OF OPERATION**
- 6. GLASS TO PASS TCLP AND PCT QUALIFICATION TESTS**

CONTAMINATED SOIL PROCESS TOP LEVEL SCHEMATIC



PLANT FEATURES

1. FEEDSTOCK STORAGE, PREPARATION, & HANDLING SYSTEM

- DRUM, CONCRETE, PLASTIC, & REBAR SHREDDING
- SOIL DRYING AND SIZING
- METAL & PLASTIC REMOVAL
- ENCLOSED SYSTEM
- NEGATIVE PRESSURE

2. FLUE GAS TREATMENT

- VENTURI SCRUBBER, WET ESP, & HEPA FILTERS
- PROCESS WATER TREATED AND RECYCLED

3. PROCESS WASTE

- RESIDUES — RECYCLED
- FINAL RESIDUALS — DISPOSAL/TREATMENT BY DOE-PADUCAH

4. RADIATION PROTECTION

- HEPA FILTER/ION EXCHANGER REPLACEMENT
- MONITORING & OPERATIONAL CONTROLS

5. TRANSPORTABILITY

- SKID-MOUNTED EQUIPMENT
- FLANGED CONNECTIONS
- MEETS DOT REGULATIONS

PLANT FEATURES

(continued)

6. PLANT LAYOUT

- APPROXIMATE FOOTPRINT: 500 FT X 350 FT
- PERIMETER FENCING

7. FOUNDATIONS

- CONCRETE PAD ON PILES FOUNDATIONS
- SEISMIC ZONE 3
- LOW SOIL BEARING STRENGTH

8. BUILDINGS

- CONTROL TRAILER
- OPERATIONS, DECON, MAINTENANCE, AND GOV'T. OFFICE TRAILERS
- EQUIPMENT WILL BE LOCATED OUTDOORS & DESIGNED FOR OUTDOOR SERVICE (EXCEPT WASTEWATER TREATMENT)

9. REQUIRED UTILITIES

- ELECTRICAL POWER AND WATER SERVICE TO SITE
- PROPANE FUEL TRUCKED TO SITE

SYSTEM BENEFITS

- **PRODUCES CHEMICALLY STABLE WASTE FORM**
- **ABILITY TO OXIDIZE AND DESTROY ORGANIC CONTAMINANTS (PCB)**
- **FLEXIBILITY IN WASTE FORM PROCESSING (MUD, CONCRETE, LLW, MIXED WASTE, PLASTICS)**
- **HIGH THROUGHPUT- 160-320 DRUMS OF MATERIAL PER DAY**
- **SUBSTANTIAL VOLUME REDUCTION**
- **LOW PROCESSING COST**
- **TRANSPORTABLE, SITE-TO-SITE OR WITHIN A SITE**

PADUCAH WASTE STREAMS

<u>WASTE STREAM</u>	<u>LBS.</u>
LOW LEVEL RADIOACTIVE WASTE	12 MILLION
PCB/LOW LEVEL WASTE	8 MILLION
RCRA LOW LEVEL WASTE	1 MILLION
PHYSICALLY- SOIL, MUD, CONCRETE, REINFORCING ROD, PLASTIC PIPE, ROCK, OTHER - IN 55 GAL. DRUMS	
THE SYSTEM HAS THE CAPABILITY TO VITRIFY 80% OF THESE WASTES AND REDUCE THE VOLUME OF EMPTY DRUMS.	

PROGRAM PARTICIPANTS

<u>ORGANIZATION</u>	<u>FUNCTION</u>	<u>CONTACT</u>
• DOE/EM-50	PROGRAM SPONSOR	DR. CLYDE FRANK
• DOE/EM-40	SITE SUPPORT	DR. JAMES OWENSDOFF
• DOE/METC	COR	MR. CLIFF CARPENTER
• DOE/PADUCAH	DEMONSTRATION HOST	MR. JIMMIE HODGES
• VORTEC	PRIME CONTRACTOR	DR. JOHN PATTEN

PROGRAM SUPPORT

<u>ORGANIZATION</u>	<u>FUNCTION</u>	<u>CONTACT</u>
• DOE/PADUCAH	EXECUTIVE ASSISTANCE	MR. JIMMIE HODGES
• JACOBS ER TEAM	EXECUTIVE ASSISTANCE	MR. DON WILKES
• LMES	EXECUTIVE ASSISTANCE	MR. JIMMY MASSEY
• SITING TEAM	SITE SUPPORT	MR. GREG SHAIA
• DOE/OAK RIDGE	OAK RIDGE SUPPORT	MR. BILL CAHILL

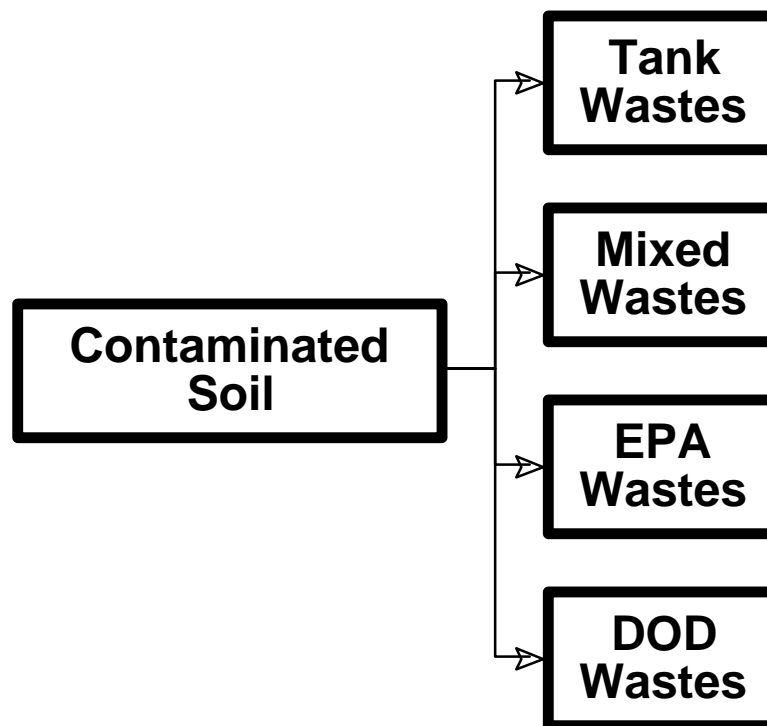
ACHIEVEMENTS

- **SUCCESSFULLY COMPLETED A SERIES OF VARIOUS VITRIFICATION TESTS**
 - Verification Tests Demonstrated the Ability to Process Surrogate Waste into Good Quality Glass
 - Produced a Glass That Passed TCLP & PCT
- **FINAL SYSTEM DESIGN COMPLETE**
- **80% OF THE COMPONENTS ON ORDER**
- **PERMITTING ON SCHEDULE WITH KY DEPARTMENT OF ENVIRONMENTAL PROTECTION**
 - Air Permit Issued July 15, 1996
 - R D &D Public Hearing Held September 19, 1996
 - RD&D Permit Public Comment Closed October 2, 1996
 - New EPA Regulations May Remove the Need for TSCA Permit
- **SITE PREPARATION INITIATED OCTOBER 2, 1996**
- **SITE DEDICATION OCTOBER**

CONCLUSIONS

- **CMS™ SYSTEM
ABILITY TO PROCESS ORGANIC AND HEAVY METAL
CONTAMINATED SOILS**
- **CMS™ SYSTEM HAS DEMONSTRATED SYSTEM
FLEXIBILITY**
 - **Soils**
 - **Tank Wastes**
 - **TSCA Waste Forms**

PLANS FOR TECHNOLOGY TRANSFER



FUTURE PROGRAM WORK

- **COMPLETE CONSTRUCTION/TESTING OF 36TPD SYSTEM**
- **EXPAND APPLICATIONS TO OTHER WASTE FORMS**
- **PURSUE PRIVATIZATION OF DOE REMEDIATION ACTIVITIES**